09/445990
301 Rec'd PCT/PTO 16 DEC 1999

Express Mail No.: **EL073777793US** Date: **December 16, 1999**

I hereby certify that this correspondence is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

ANTONELLA FUSILLO
(Name of person mailing paper or fee)

(Signature)

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		Attorney's Docket No: **LANGHANS**
INTERNATIONAL APPLICATION NO. **PCT/EP99/02724**	**INTERNATIONAL FILING DATE** **April 22, 1999**	**PRIORITY DATE CLAIMED** **April 22, 1998 & June 10, 1998**

TITLE OF INVENTION
RESONATOR ARRANGEMENT FOR SOLID STATE LASERS

APPLICANT(S) FOR DO/EO/US
LUTZ LANGHANS & THOMAS RENNER

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.

2. [ ] This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.

3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).

4. [ ] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US)

6. [X] A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.

8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. [X] Original or facsimile of an oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. concern other document(s) or information included:

11. [X] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. [X] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. [X] A **FIRST** preliminary amendment.
    [ ] A **SECOND** or **SUBSEQUENT** preliminary amendment.

14. [ ] A substitute specification.

15. [ ] A change of power of attorney and/or address letter.

16. [X] Other items or information: International Search Report and Form PTO-1449/ Form PCT/IB/308

514 Rec'd PCT/PTO 16 DEC 1999

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NO.
09/463990	PCT/EP99/02724	LANGHANS

17. [X] The following fees are submitted : BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5): [X] For filing with EPO or JPO search report (37 C.F.R. 1.492(a)(5)) **$ 840.00** [ ] International preliminary examination fee paid to USPTO (37 C.F.R. 1.492(a)(1)) **$ 670.00** [ ] No international preliminary examination fee paid to USPTO (37 C.F.R. 1.492(a)(2)) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2)) **$ 760.00** [ ] Neither international preliminary examination fee paid to USPTO (37 C.F.R. 1.492(a)(3)) nor international search fee paid to USPTO (37 C.F.R. 1.445(a)(2)) **$ 970.00** [ ] International preliminary examination fee paid to USPTO (37 C.F.R. 1.492(a)(4)) and all claims satisfied provisions of PCT Articles 33(2)-33(4) **$ 96.00**	**$840.00**
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	

Claims	Number Field	Rate	
Total Claims	11-20	x $ 18.00	
Independent Claims	2-3	x $ 78.00	
Multiple dependent claims (if applicable)		x $260.00	
		TOTAL OF ABOVE CALCULATIONS	**$840.00**
Reduction by 1/2 for filing by small entity, if applicable. Verified small entity statement must also be filed. (Note 37 CFR 1.9,1.27,1.28)			
		SUBTOTAL	**$840.00**
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date 37 CFR 1.492(f).			
		TOTAL NATIONAL FEE	**$840.00**
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +			**$ 40.00**
		TOTAL FEES ENCLOSED	**$880.00**
		Amount to be refunded	
		charged	

a. [X] A check in the amount of **$880.00** to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. **06-0502** in the amount of $ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **06-0502**. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending status.

Send all correspondence to:

HENRY M. FEIEREISEN
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(212) 244-5500
Date: December 16, 1999

HENRY M. FEIEREISEN
Registration No. 31,084

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Docket No.: LANGHANS

In re Application of:	)
LUTZ LANGHANS & THOMAS RENNER	)
Int. Appl. No.: PCT/EP99/02724	)
Int. Filing Date: April 22, 1999	)
For: RESONATOR ARRANGEMENT FOR SOLID STATE LASERS	)

PRELIMINARY AMENDMENT

Express Mail mailing label number. **EL073777793US**
Date of Deposit **December 16, 1999**
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ANTONELLA FUSILLO
(Name of person mailing paper or fee)

(Signature)

Assistant Commissioner for Patents
Washington, D.C. 20231

S I R:

Preliminary to the first Official Action in the above-entitled application, please amend the application as follows:

IN THE SPECIFICATION:

Page 4, line 13, add the heading --BRIEF DESCRIPTION OF THE DRAWING--.

Page 5, line 18, add the heading --DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS--.

Page 15, first line, delete completely, and after the heading "CLAIMS" and before the first claim add --What is claimed is:--.

IN THE CLAIMS:

Amend the following claims:

3. (Amended) The resonator according to the preamble of claim 1, characterized in that the rear mirror is convex, that the end of the laser rod facing the rear mirror is also convex, and that the output mirror is arranged in close proximity to the end of the laser rod[, preferably at a distance of less than approximately 10 mm].

5. (Amended) The resonator according to the preamble of claim 4, characterized in that the rear mirror is convex, that the end of the laser rod facing the rear mirror is planar, that the other end of the laser rod is convex, and that the output mirror is arranged in close proximity to the end of the laser rod[, preferably at a distance of less than approximately 10 mm].

6. (Amended) Resonator according to [one of the claims 1 to 5] claim 1, characterized in that the laser rod is a Nd:YAG, Er:YAG, Ho:YAG, Nd:glass rod.

Add the following claims:

7. (New) Resonator according to claim 3, characterized in that the laser rod is a Nd:YAG, Er:YAG, Ho:YAG, Nd:glass rod.

8. (New) Resonator according to claim 4, characterized in that the laser rod is a Nd:YAG, Er:YAG, Ho:YAG, Nd:glass rod.

9. (New) Resonator according to claim 5, characterized in that the laser rod is a Nd:YAG, Er:YAG, Ho:YAG, Nd:glass rod.

10. (New) The resonator according to the preamble of claim 3, characterized in that the output mirror is arranged at a distance of less than approximately 10 mm to the end of the laser rod.

11. (New) The resonator according to the preamble of claim 5, characterized in that the output mirror is arranged at a distance of less than approximately 10 mm to the end of the laser rod.

REMARKS

This Amendment is submitted preliminary to the issuance of an Office Action in the present application.

Applicant has amended claims 3, 5, 6 to delete any reference to "preferably" and to eliminate the multiple dependency of claim 6. Claims 7 to 11 have been added to set forth features deleted from the amended claims. In addition, applicant has amended the specification to present it in proper form and language. Especially, applicant has provided the specification with proper headings.

When the Examiner takes this application up for action, he is requested to take the foregoing into account.

The Commissioner is hereby authorized to charge fees which may be required, or credit any overpayment to Deposit Account No. 06-0502.

Respectfully submitted,

By: _____
Henry M. Feiereisen
Agent for Applicant
Reg. No. 31,084

Date: December 16, 1999
350 Fifth Avenue
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HMF:af

RESONATOR ARRANGEMENT FOR SOLID STATE LASERS

TECHNICAL FIELD AND STATE-OF-THE-ART

During the past years, Nd:YAG welding lasers have found increasing applications in the areas of jewelry and dentistry. These so-called handheld welding lasers are suitable to perform precise point and seam welding in the sub-millimeter region. They have not only the advantage of providing solder-free joints, but also protect the workpiece as compared to the conventional flame welding technique. A typical construction of devices presently on the market is illustrated in FIG. 1. The conventional "classic" resonators are mostly constructed in the manner illustrated in FIG. 2a and have a planar output mirror 2 and a concave reflecting mirror 3. The Nd:YAG laser rod 1 is located approximately in the center between the mirrors 2 and 3.

The exiting laser beam 4 is focused onto the work plane 8 by a beam expander 5 with an adjustable divergence, a turning mirror 6 (for example, 1064 nm - HR, visible range - AR) and a focusing lens 7.

All devices encounter problems associated with "thermal lensing" of the Nd:YAG rod and the "initial pulse characteristics" associated therewith. Pumping with a flash lamp and water cooling produces a radial temperature profile in the Nd:YAG rod, which is transformed by the characteristic material constant dn/dT

into a refractive index profile and thereby into a lensing effect. Depending on the injected pump energy and the cooling provided by the cooling water, respectively, this lensing effect depends on the pump power. FIG. 3 illustrates the initial pulse characteristics for a state-of-the-art "classic resonator", wherein the spot size at the focal point is simulated without beam expansion as a function of the pump power, i.e. with varying thermal lensing effect and for different radii of the reflecting mirror. The increase of the focal diameter with increasing pump power is clearly seen. Smaller radii of curvature of the reflecting mirror lead to a smaller relative change, but to overall larger values of the focal diameter. For single pulses or for initial pulses (low pump power), the lensing effect is still small. For continuous pulses (high pump power) and a predetermined frequency the lens increases to a value which depends on the average pump power in continuous operation. This lensing effect affects the beam quality and thereby also the spot size in the work plane as well as (to a lesser degree) the pulse energy. The user who is mainly interested in the energy density, i.e. the pulse energy divided by the spot size, will recognize this phenomenon as a strongly variable welding outcome which depends on the welding history.

One possibility to avoid this problem is to transmit the laser beam through a sufficiently long glass fiber. Since the glass fiber does not preserve the diameter of the beam, the beam which is coupled out typically has a constant diameter and an approximately constant divergence. However, this approach degrades the beam quality, so that the focusing unit has to be adapted

accordingly. Moreover, the so-called "benign behavior" of the welding process suffers, since the depth of focus in the work plane is reduced. Another possibility to avoid this problem is to use a stronger beam expansion before the beam splitter and to also work outside the focusing range, where the image of the rod surface remains approximately constant. This approach also reduces the initial pulse characteristics. However, the "benign behavior" is again adversely affected (depth of focus of the laser focusing system in the work plane).

The publication by MAGNI, V. et al.: "Recent Developments In Laser Resonator Design" in Optical and Quantum Electronics 23, 1991, pp. 1105-1134, in particular page 1106, second paragraph, describes additional measures to counteract or even compensate the effect of thermal lensing. These conventional measures, however, are only effective at a specified value of the pump power.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a stable resonator which is stable over an extended range of the pump power against the effects caused by thermal lensing, rather than only at a specific value of the pump power. The resonator according to the invention should also reduce the initial pulse characteristics below the detection limit of the user, while at the same time maintaining the "benign behavior", i.e. the depth of focus, of the laser.

The solution of this object is provided by resonators as described in the commensurate claims 1, 3, 4 and 5. The applicant has realized that, unlike in state-of-the-art devices, the beam quality as a function of the pump power has a comparably flat maximum for relatively short resonator lengths due to the extremely asymmetric construction of the resonators according to the invention. Accordingly, the applicant achieves a comparably constant beam quality over a larger pump power range. As a result, the thermal lensing effect has no effect or only an insignificant effect on the welding result; the characteristics features of the initial pulse are negligibly small. While the laser rod in the embodiments recited in the commensurate claims 1 and 4 is completely displaced towards the output side, in the other advantageous embodiments recited in claims 3 and 5 the laser rod may be located at a very short distance from the output mirror.

The invention will be described hereinafter with reference to the Figures and diagrams showing calculated and measured values. It is shown in:

FIG. 1 a Nd:YAG welding laser according to the state-of-the-art;

FIG. 2a a classic resonator according to the state-of-the-art;

FIG. 2b a first embodiment of a resonator according to the invention (so-called "sweet-spot"-resonator I);

FIG. 2c a second embodiment of a resonator according to the invention (so-called "sweet-spot"-resonator II);

FIG. 3 a simulation of the initial pulse characteristics for a state-of-the-art classic resonator;

FIG. 4 the focus diameter of a state-of-the-art resonator (upper curve) and of a "sweet-spot"-resonator of the invention (lower curve) as a function of the pump power (simulation);

FIG. 5 the focus diameter of a state-of-the-art resonator (upper curve) and of a "sweet-spot"-resonator of the invention for different laser rods (lower four curves) as a function of the pump power (measured values);

FIG. 6 the beam quality M as a function of the pump power in multi-mode operation for a resonator arrangement with L= 650 mm, R = infinite, f= infinite (curve 1), and f= 1800 mm (curve 2)

According to FIG. 2b, the resonator of the invention has an extremely asymmetric configuration. The laser rod 1 is planar on the output side and completely displaced towards the output side, wherein the planar rod end is provided with a semi-reflecting layer 10 to couple out the laser beam 4.

The other rod end 11 has a convex curvature and operates as a focusing lens in the resonator. The rear reflecting mirror 12 also has a convex curvature. This special arrangement of the components in conjunction with a suitable arrangement of the resonator lengths and the respective radii of curvature provides a resonator which produces a small focus with a short overall length, wherein the focus is almost independent of the frequency and the pump power, respectively. The components may be arranged as follows:

Length of the resonator: 290 mm

Radius of curvature of the rear mirror: 0.1 m convex (cvx)

Radius of curvature of the Nd:YAG rod: 0.22 m convex (cvx)

Length of Nd:YAG rod: 90 mm

The measured values illustrated in FIG. 5 relate to the aforedescribed resonator.

FIG. 4 shows a simulated comparison between a "classic" resonator (upper curve) and the novel "sweet spot" resonator according to FIG. 2b (lower curve). As seen in FIG. 4, the "sweet spot" resonator not only has an approximately constant focus diameter, whereas the focus diameter of the "classic" resonator increases with increasing pump power and therefore also with increasing thermal lensing effect; moreover, the focus diameter is significantly smaller across the entire range. The calculated results are supported by the measurements shown in FIG. 5 (1 "state-of-the-art" rod, 4 different rods of the "sweet spot" resonator according to the invention). The measurements were

taken with a CCD camera; other data are: focusing lens with f = 116 mm, Pmax= 1.5 kW and a distance from the focusing lens to the end of the rod = 450 mm.

Similar results can be all obtained with slightly altered parameters (radius of curvature & resonator length).

The relevant feature is that at the exemplary pump powers the resonator length can be reduced to a value significantly less than 500 mm by using two convex radii (rear mirror & rod).

Using a commercially available computer program for resonators and based on the observations by the applicant, that the welding result are unaffected by thermal lensing effects over a large range of pump power in particular with an extremely asymmetric resonator, additional resonator configurations can be determined as follows.

The beam quality M2 is computed with the computer program for resonators and the function of the pump energy and is printed as a curve (FIG. 6). (M2 is used instead of M^2)

1. The program is initiated with an extremely asymmetric planar-planar resonator configuration, i.e., the laser rod is not curved (corresponds to an

internal lens with a focal length f = infinite, and the radii of curvature of both the rear mirror and the output mirror are also R = infinite; with these boundary conditions, the beam quality M2 is calculated as a function of pump energy for different values of the resonator length L and a specific value of L (Lo) is determined, where the beam quality has the desired maximum value (in the present example, the maximum value is set to be M2=25, which is a typical value for laser welding applications). The position of the maximum does not change when L is varied. The curve, however, bulges upwardly (for values of L less than Lo) or collapsed downwardly (for values of L greater than Lo).

2. If the maximum of the beam quality M2 is not located in the range of pump powers where the system is to be operated according to the application-specific conditions, as in the aforedescribed asymmetric planar-planar resonator configuration, then the radius of curvature of the end of the laser rod which faces the rear mirror, decreases from planar, i.e., R(rod)= infinite, and becomes finite. The lens formed by the curved surface can also be employed to characterize the resonator instead of the radius of curvature of the end of the laser rod. The focal length of the curved end of the laser rod therefore varies from planar, i.e. f = infinite and decreases to finite values. Accordingly, different f-values are entered into the computer program, wherein the maximum shifts to the left to smaller pump powers with decreasing f-values. The value fo, for which the maximum of the curve is located in the center of the desired pump power range, is determined by trial

and error. In the present example, the center of the desired pump power range is approximately 1 kW, ranging from 0 to 2 kW.

3. If a shorter resonator is to be used with the same value of M2 = 25 to attain a more compact system (as is usually the case), then the beam quality M2 is again calculated, as under item 1 above, for a planar-planar resonator, i.e., the laser rod is not curved (corresponds to an internal lens with a focal length of f= infinite) and the radii of curvature of the rear mirror and of the output mirror are infinite. Since L is now smaller than Lo, the maximum is now greater than M2 = 25 (see item 1 above, last sentence). The radius R of the rear mirror is now reduced until the maximum is again at 25.

4. The focal length of the curved end of the laser rod is then reduced according to item 2, until the maximum falls again in the center of the desired pump power range, in the present example approximately 1 kW, ranging from 0 to 2 kW. The result is a novel resonator with the desired characteristics.

With a similar process, additional resonator arrangements can be determined for M2 = 25 by adjusting R for the desired L so that the maximum is = 25 and by shifting the location of the maximum by varying f. Accordingly, the respective values of R and f can be determined for other values of M2 and the desired resonator lengths L.

In the following, several values are listed for a "sweet spot" resonator according to the invention, wherein the rod has a length of 85 mm. Other rod lengths give slightly different results.

L	f	R
Resonator length (mm)	Focal length of the internal lens (mm)	Radius of the rear mirror (mm)
650	1800	- ∞
320	325	-170
290	270	-100
265	230	-85
215	155	-40

The values in the table can be described empirically by the following formulas:

$$R = \text{const} \times (L/Lo-L)^2$$

$$f = f_0 \times (L/Lo)^{2.4}$$

In a second embodiment shown in FIG. 2c, the "sweet spot" resonator II of the invention is constructed so that the laser rod 1 is planar on the side facing the convex rear mirror 12, and is convex and semi-reflecting on the opposite side which is the output side. This embodiment has the same advantages as the

"sweet spot" resonator I illustrated in FIG. 2b. With a corresponding design of the resonator length and the respective radii of curvature, this special arrangement of the components also provides a resonator which has a short overall length and produces a small focus which is substantially independent of the frequency and the pump power.

In the following, several value are listed for a "sweet spot" resonator II according to the invention (rod length = 85 mm).

L	A	R
Resonator length (mm)	Radius of the output mirror or rod end (mm)	Radius of the rear mirror (mm)
650	2000	- ∞
320	400	-240
290	350	-175
265	300	-140
215	215	-70

The table was created in the same manner as for "sweet spot" resonator I.

The beam quality M2 is calculated using a commercially available computer program for resonators as a function of the pump energy and printed as a curve.

1. The length Lo is determined for a planar-planar resonator configuration with A = infinite, so that the maximum value of M2 assumes a predetermined value (in this case M2 = 25).

2. The value for A_o is then determined in such a way that the maximum value of the curve is located in the center of the desired pump power range (in this case at 1 kW, range 0-2 kW).

This completes the first line.

If shorter resonators with the same properties are desired, then the following process applies:

3. The M2 curve is calculated for a shorter length L < Lo, and a curve with a maximum value of greater than 25 is obtained. The value for R is then lowered until the maximum is again located at 25.

4. The value for A is then lowered until the maximum is again located at the center of the desired range.

This process produces a new resonator with the desired features. In this way, respective values of R and A can be determined for each specified value of M2 and L.

These values can also be determined empirically by the following formulae:

$R = C \times (L/Lo-L)^{1.9}$ C= -254

$A = A_0 \times (L/Lo)^{2.1}$

It should be noted that the pulse energy is also almost independent of the history of the pump power. Accordingly, both the focus diameter and the energy density remain constant, which is of paramount interest for the user.

The preferred field of application of this invention are Nd:YAG welding lasers with a resonator length of less than 500 mm and a maximum average pump power of up to 2 kW (this corresponds to approximately 60 W average laser power).

LIST OF REFERENCE NUMERALS

1	Nd:YAG laser rod
2	output mirror
3	concave rear mirror
4	laser beam
5	beam expansion with divergence adjustment
6	turning mirror
7	focusing lens
8	focusing plane of the observation (work plane)
9	observation direction
10	semi-reflecting layer
11	convex end of the rod
12	convex rear mirror

RESONATOR ARRANGEMENT FOR SOLID-STATE LASERS

CLAIMS

1. Stable resonator for solid-state lasers which exhibit a thermally induced lensing effect, with a laser rod, a rear mirror and a semi-reflecting output mirror, characterized in that the rear mirror is convex, that the end of the laser rod facing the rear mirror is also convex, and that the output mirror is formed by the other end of the laser rod, wherein this end is semi-reflecting.

2. The resonator according to claim 1, characterized in that the semi-reflecting end of the laser rod is formed planar.

3. The resonator according to the preamble of claim 1, characterized in that the rear mirror is convex, that the end of the laser rod facing the rear mirror is also convex, and that the output mirror is arranged in close proximity to the end of the laser rod, preferably at a distance of less than approximately 10 mm.

4. Stable resonator for solid-state lasers which exhibit a thermally induced lensing effect, with a laser rod, a rear mirror and a semi-reflecting output mirror, characterized in that the rear mirror is convex, that the end of the laser rod facing the rear mirror is planar, that the other end of the laser rod is convex, and that the output mirror is formed by the other end of the laser rod, wherein this end is semi-reflecting.

5. The resonator according to the preamble of claim 4, characterized in that the rear mirror is convex, that the end of the laser rod facing the rear mirror is planar, that the other end of the laser rod is convex, and that the output mirror is arranged in close proximity to the end of the laser rod, preferably at a distance of less than approximately 10 mm.

6. Resonator according to one of the claims 1 to 5, characterized in that the laser rod is a Nd:YAG, Er:YAG, Ho:YAG, Nd:glass rod.

ABSTRACT

A stable resonator for solid-state lasers which exhibit a thermally induced lensing effect, includes a laser rod, a rear mirror and a semi-reflecting output mirror. The invention is characterized in that the rear mirror has an extremely asymmetrical configuration, allowing the laser rod to move totally or almost totally toward the side of the output mirror. The laser rod is curved in a convex manner on one end in order to achieve a refractive effect, and a convex rear mirror is provided. As a result of the extreme asymmetry, the resonator has a beam quality as a function of the pump power with a comparably flat maximum even at relatively short resonator lengths in contrast to the state of the art. The effects of the thermal lens have practically no influence on processing results. Starting pulse behavior lies below the detection limit.

FIG.1

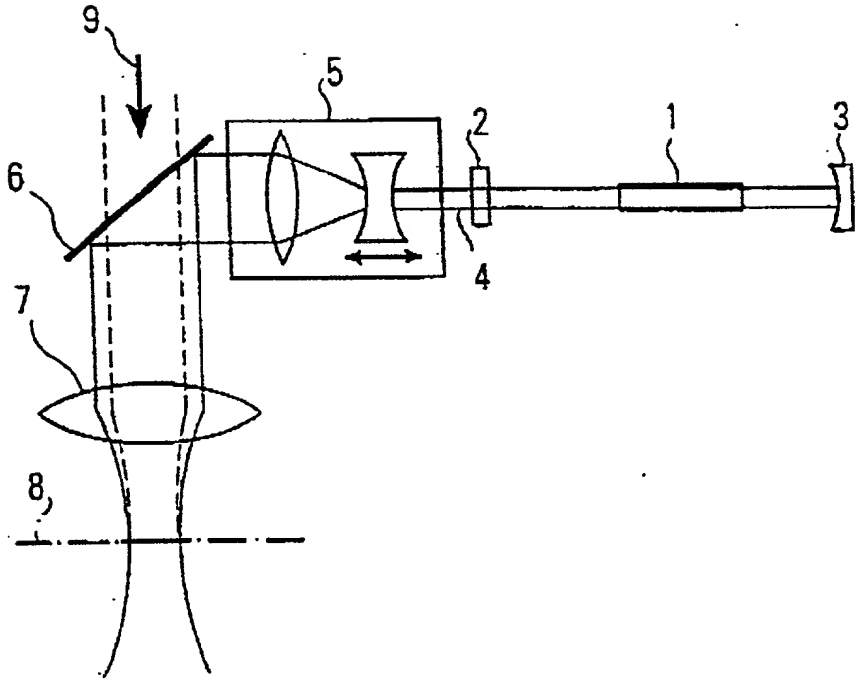


FIG.2a

Prior Art

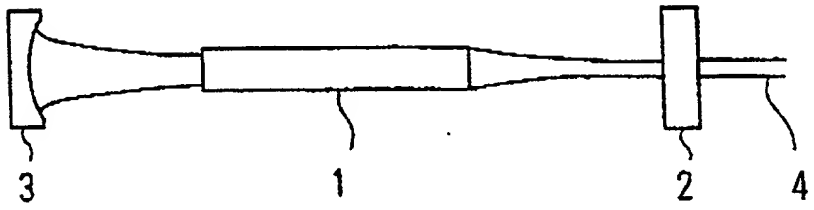


FIG.2b

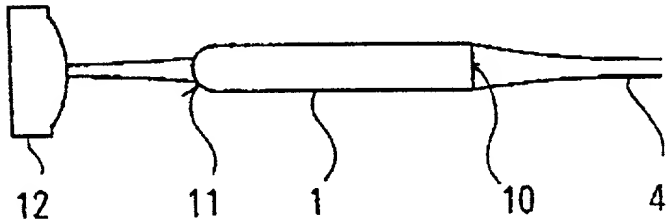


FIG.2c

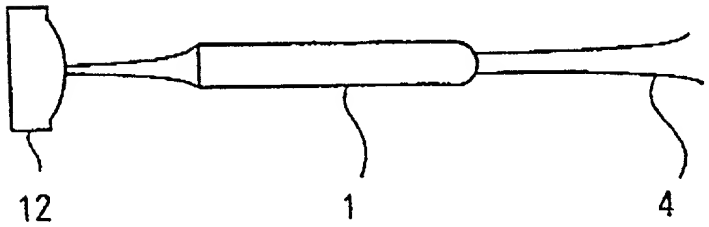


FIG.3

Initial pulse characteristics for a "classic" resonator (prior art)
Simulation

Focusing lens: f= 116 mm
Distance Focusing lens-end of resonator: 285 mm
Resonator length: 325 mm
Rod length: 90 mm
Radius of curvature: rear mirror: see legend
Radius of curvature of output mirror: planar

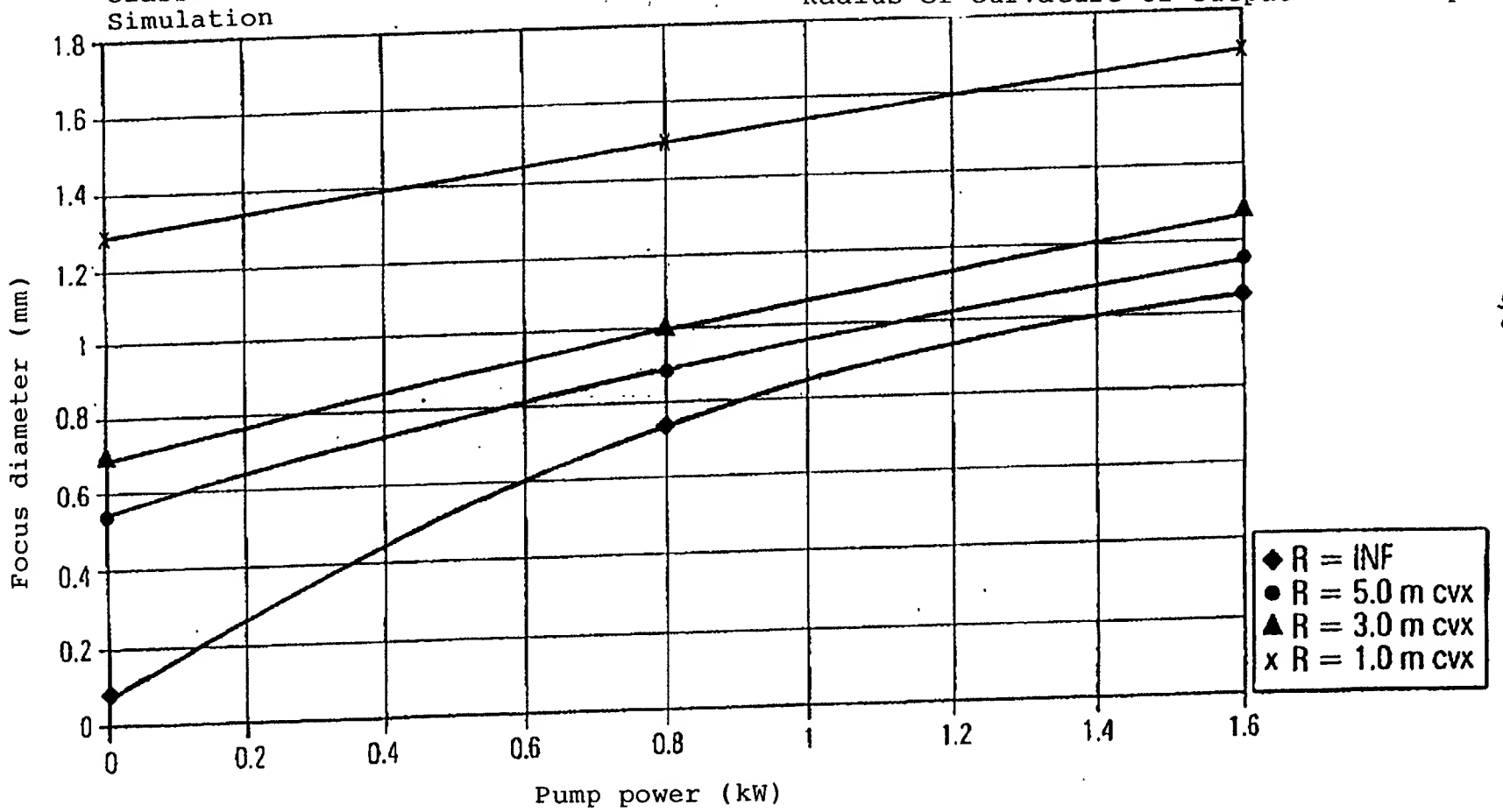


FIG.4

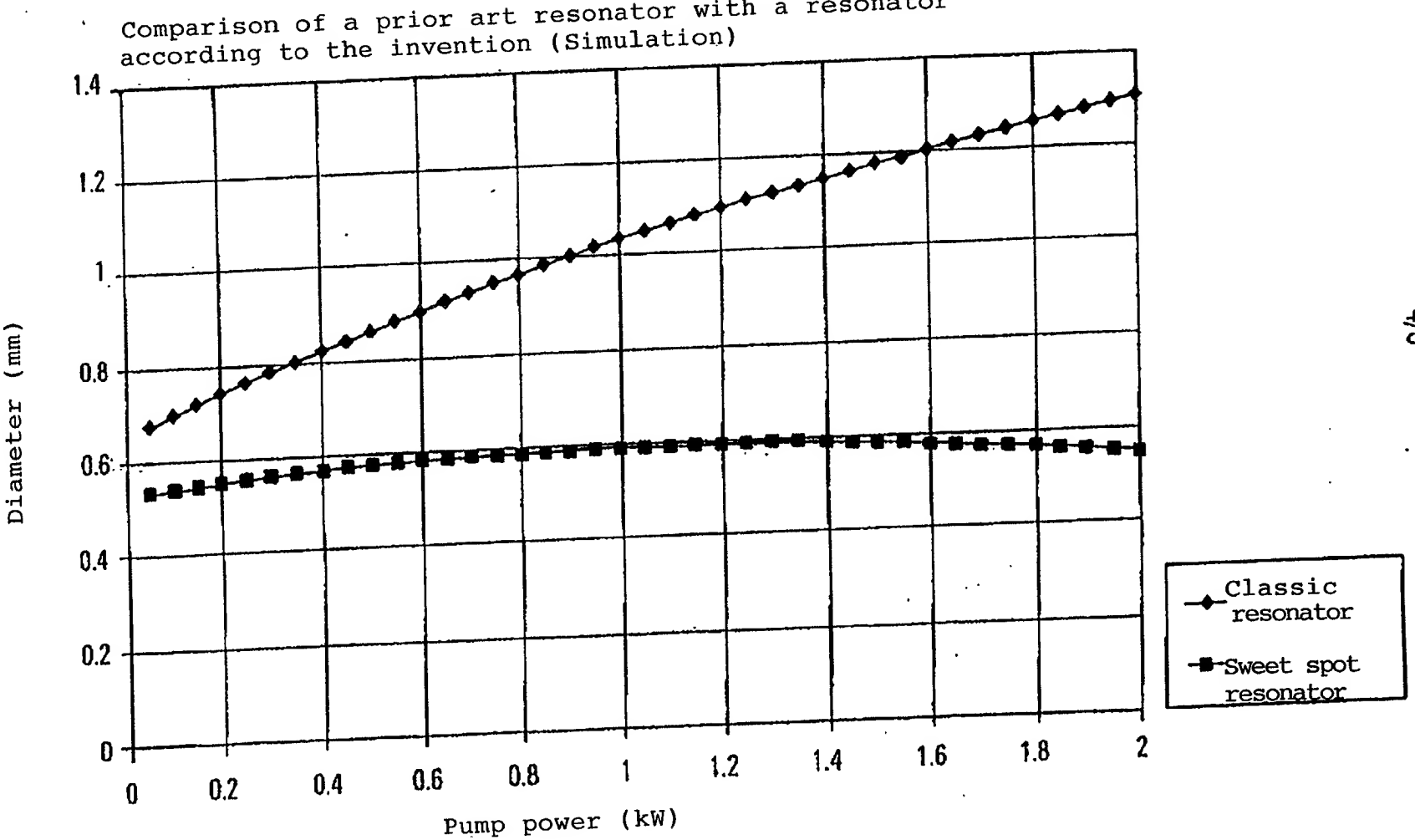

Comparison of a prior art resonator with a resonator according to the invention (Simulation)
Diameter (mm)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Pump power (kW)
Classic resonator
Sweet spot resonator

FIG.5

Sweet spot resonator according to the invention / Area initial pulse characteristics (measured values)

Measured with CCD camera
Focusing lens: f= 116 mm
Pmax= 1.5 kW
Distance Focusing lens-rod end: 450 mm
Resonator length: 290 mm
Rear mirror: R=0.1m (cvx)
Rod curvature: 0.22m (cvx)
Rod length: 90 mm

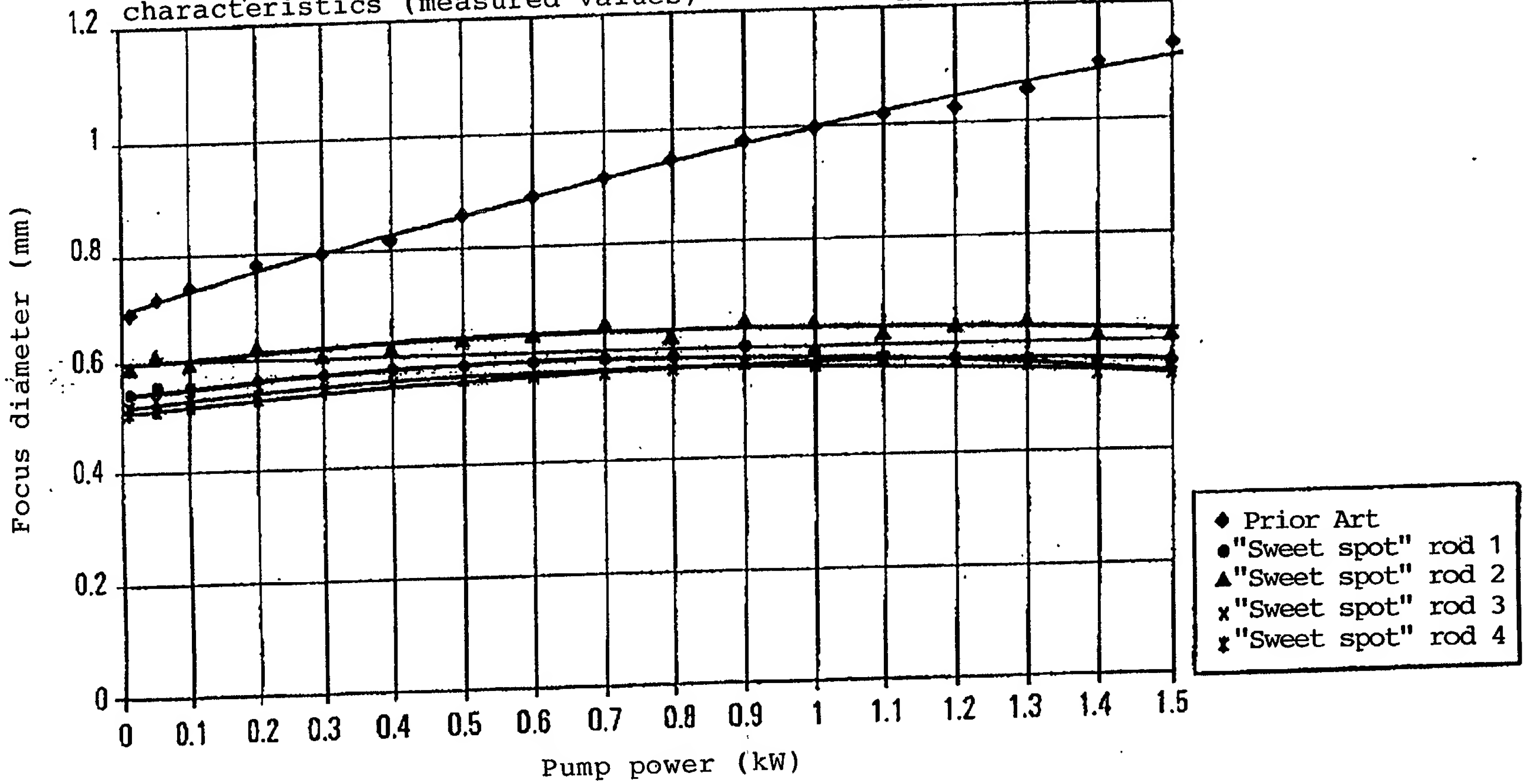
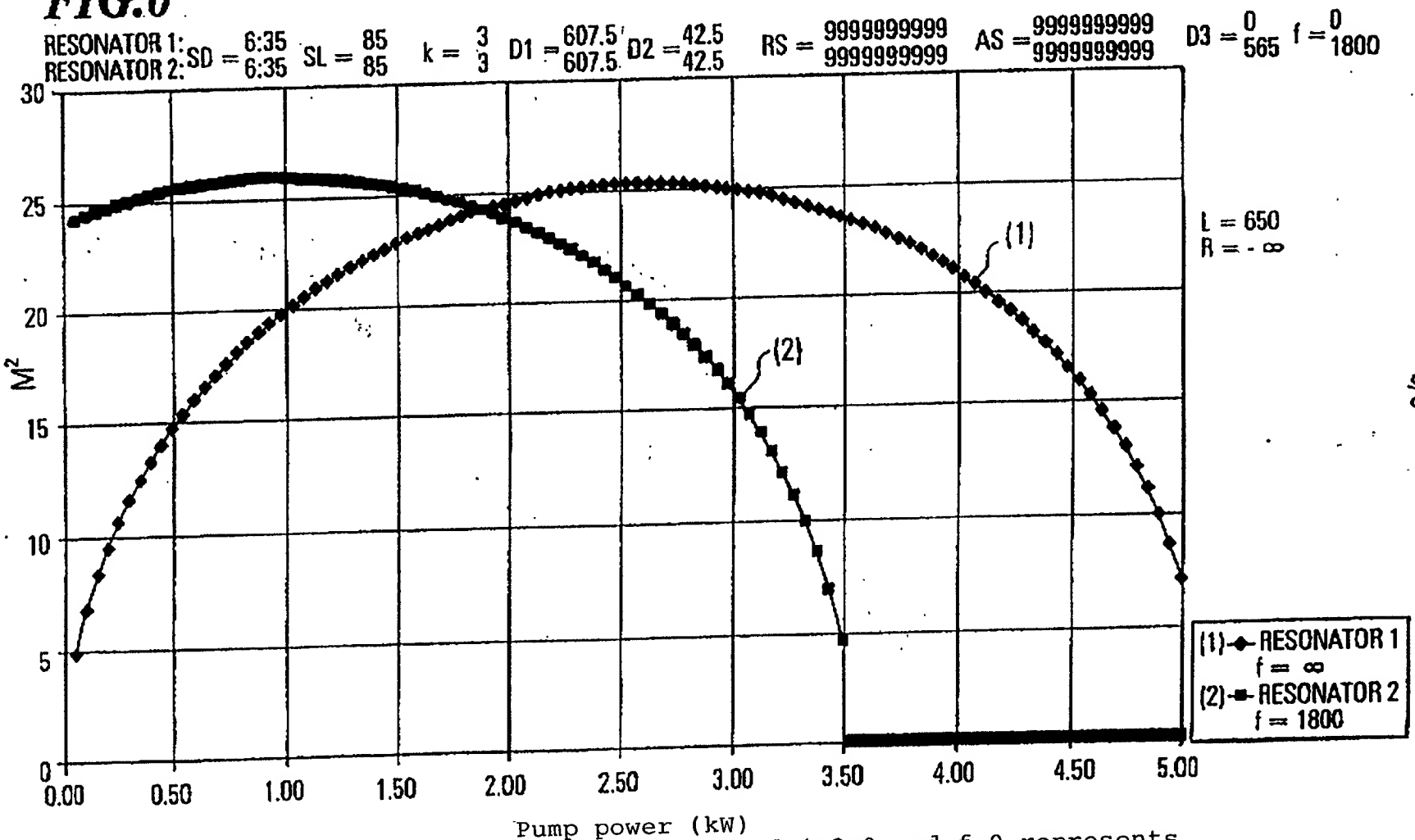


FIG.6 Multi-mode output side: M^2



Resonator with lens between rear mirror and rod (D3=0 and f=0 represents calculation without lens)

VERIFICATION OF A TRANSLATION

I, HENRY M. FEIEREISEN, resident of the United States, having a place of business at 350 Fifth Avenue, Suite 3220, New York, N. Y. 10118, depose and state that:

1. I am familiar with the English and German languages.

2. I have read the attached German language international patent application PCT/EP/02724.

3. The hereto attached English language text is an accurate translation thereof.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Henry M. Feiereisen

Date:

Declaration and Power of Attorney for Patent Application
Erklärung für Patentanmeldungen mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

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RESONATORANORDNUNG FÜR FESTKÖRPERLASER

deren Beschreibung
(zutreffendes ankreuzen)

[ ] hier beigefügt ist.
[X] wurde angemeldet am 22. April 1999 unter der U.S.-Anmeldungs Nr. oder unter der Internationalen Anmeldenummer im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesens (PCT) PCT/EP99/02724 und am _____ abgeändert (falls zutreffend).

Ich bestätige hiermit, daß ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell duch einen Zusatzantrag, wie oben erwähnt, abgeändert wurde.

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My residence, post office address and citizenship are stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

RESONATOR ARRAY FOR SOLID-STATE LASERS

the specification of which
(check one)

[ ] is attached hereto
[X] was filed on 22 April 1999 as United States Application Number or PCT International Application Number PCT/EP99/02724 ,and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Applications (Frühere ausländische Anmeldungen)			Priority Claimed? Priorität beansprucht?	
198 17 848.4 (Number) (Nummer)	Germany (Country) (Land)	22/April/1998 (Day/Month/Year Filed) (Tag/Monat/Jahr eingereicht)	[X] Yes Ja	[ ] No Nein
198 25 827.5 (Number) (Nummer)	Germany (Country) (Land)	10/June/1998 (Day/Month/Year Filed) (Tag/Monat/Jahr eingereicht)	[X] Yes Ja	[ ] No Nein

Ich beanspruche hiermit gemäss Titel 35, US-Code, §119(e), den Vorzug aller unten aufgeführten US-Hilfsanmeldungen

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(Application No. / Anmeldenr.) (Filing Date / Anmeldedatum)

(Application No. / Anmeldenr.) (Filing Date / Anmeldedatum)

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(Appl. No.) (Anmeldenr.)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig aufgegeben)	(Status) (patented, pending abandoned)
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Ich erkläre hiermit, daß alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und daß ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, daß wissentlich und vorsätzlich falsche Angaben gemäss §. 1001, Titel 18 US-Code strafbar sind und mit Geldstrafe und/oder Gefängnis bestraft werden können, und daß derartig wissentlich und vorsätzlich falsche Angaben die Rechtswirksamkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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